SNR enhancement of intermolecular double-quantum coherence MRS in inhomogeneous fields with phased array coils

Y. Lin[1,2], Z. Chen[1], and J. Zhong[2]

[1]Physics, Xiamen University, Xiamen, Fujian, China, People's Republic of, [2]Imaging Sciences, University of Rochester, Rochester, New York, United States

Introduction

To obtain high-resolution magnetic resonance spectra (MRS), a homogeneous magnetic field is prerequisite with conventional methods. However, magnetic field homogeneity in vivo is often degraded in a large volume of human or animal tissues or in volumes with mixed tissues. Intermolecular double-quantum coherences (iDQCs), have been used to remove the effect of static field inhomogeneity [1-3]. High-resolution MRS of whole cerebellum in humans was obtained via detecting iDQC signal using a CP birdcage head coil on a 3-T clinical scanner [3]. But, the low signal-to-noise (SNR) limits further applications of the iDQC method. Here, we try to improve the SNR of iDQC MRS through using a phased array head coil relative to CP head coil.

Methods

Experiments were carried out on a Siemens 3-T TIM Trio whole-body scanner. Both a standard CP birdcage head coil and a 32-channel phased array head coil were utilized for signal reception. The corresponding RF excitation was achieved with the CP head coil and the body coil respectively. A proton MRS phantom with cylindrical shape and metabolite composition similar to that of a normal human brain was used. A two-dimensional (2D) iDQC pulse sequence with PRESS localization module was employed to perform iDQC measurement [3]. The spectral width was 250 Hz with 128 increments for F1 dimension and was 1000 Hz for F2 dimension. A voxel volume of $60\times60\times60$ mm^3 was chosen with the voxel center located at isocenter unless otherwise specified. In order to mimic a circumstance of inhomogeneous magnetic field, shimming was intentionally misadjusted to produce a linewidth of about 60 Hz for the water resonance. The standard PRESS sequence was employed to acquire the conventional single-quantum signal. The PRESS was performed on a voxel volume of $60\times60\times60$ mm^3 in inhomogeneous field (described above) and on a voxel volume of $20\times20\times20$ mm^3 in homogeneous field. The raw data acquired with both localized 2D iDQC and PRESS sequences were saved and processed using custom-made software based on Matlab 6.5.0.

The multichannel nonparametric singular value decomposition (SVD) algorithm was utilized to combine multiple spectra acquired with the 32-channel phased array coil [4,5]. Combining the signal from a phased array coil is to make a weighted sum of the n fids. This can be expressed as $S(t) = \sum w_j S_j(t)/\text{sqrt}(\sum \overline{w_j} w_j)$, where $S_j(t)$ is the signal from the coil j, w_j is the weighting factor, j represents coils with $j = 1,2,\ldots,n$, and t represents time points with $t = 1,2,\ldots,m$. The iDQC fid data matrix $\mathbf{A}$ was constructed as a $mk\times n$ matrix (2D matrix), where m is the number of measured data points in the fid for each t_1, k is the number of t_1 steps in the 2D iDQC experiment, and n is the number of coils. $\mathbf{A}$ comprises the sum of a signal term $\bar{\mathbf{A}}$ and a noise term $\mathbf{N}$, $\mathbf{A} = \bar{\mathbf{A}} + \mathbf{N}$. Then, a Rank 1 approximation of $\mathbf{A}$ using SVD, $\mathbf{A} = \mathbf{USV'}$, is made. The signal vector can be estimated from the principle column of $\mathbf{U}$. The weighting factor w_j can be obtained in the principle column of $\mathbf{V}$, or from the eigenvector corresponding to the largest eigenvalue of $\mathbf{A'A}$.

Results and Discussion

The spectra in Fig. 1 were obtained using the 32-channel coil with a voxel volume of $60\times60\times60$ mm^3 in the inhomogeneous field of about 60 Hz for water resonance. The results from the CP head coil were not displayed due to their appearance similar as those from 32-channel coil. The 2D localized iDQC pulse sequence was performed using both CP head coil and 32-channel coil in the same/similar inhomogeneous field as in Fig. 1. The obtained 2D iDQC spectra (see the example in Fig. 1b) were counterclockwise rotated by 63.4°, then projected onto the F2 axis. The resulting 1D projection spectra are shown in Fig. 2c and d. They hold similar resolution as those in Fig. 2a and b which were acquired by PRESS in homogeneous field with the voxel volume of $20\times20\times20$ mm^3. The three major metabolite peaks, NAA, Cr and Cho, are clearly resolved in Fig. 2c and d. In Fig. 2, both the PRESS and iDQC spectra from 32-channel coil have the SNR (defined as the ratio of NAA peak intensity to the standard deviation of signal in the region between 7.0 and 8.0 ppm) about twice of those from the CP head coil through comparing Fig. 2d to c and b to a. To investigate the influence of voxel position relative to the phased array coil on iDQC SNR, voxel center was moved away from isocenter 15 mm along the directions of head, foot, anterior, and posterior respectively (see the schematic position of voxel center relative to coil in Fig. 3). The gain of iDQC SNR in the 32-channel over the CP head coils ranges from 1.6 to 2.5 times (see the detailed values in Fig. 3) . The variation reflects the dependence of sensitivity of phased array coil on the distance between the coil and voxel, since the 32-channel coil is asymmetric in the coil element distribution along the directions of head-foot and anterior-posterior. These results suggest that enhancement of iDQC SNR can be achieved through using phased array coils. This will provide great help for iDQC applications of high-resolution in vivo spectroscopy in the presence of field inhomogeneity. The gain in SNR however can be dependent on the relative location of the voxels in the coil and caution is needed in spectrum quantification.

References

[1] Chen Z, et al. *J. Am. Chem. Soc.* 126:446-447 (2004).
[2] Chen Z, et al. *J. Chem. Phys.* 130:084504 (2009).
[3] Lin YQ, et al. *Magn. Reson. Med.* (2009) in press.
[4] Sandgren N, et al. *J. Magn. Reson.* 175:79-91(2005).
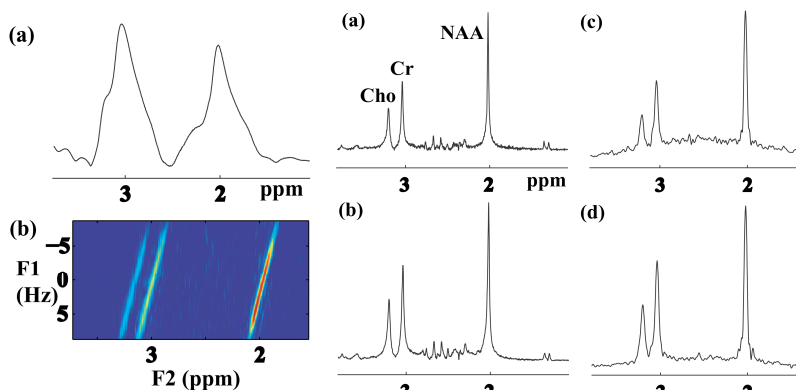[5] Bydder M, et al. *Magn. Reson. Imag.* 26 :847-850 (2008).

Fig. 1. (a) 1D PRESS spectrum acquired in the inhomogeneous field, (b) 2D iDQC spectrum acquired in the same inhomogeneous field as (a).

Fig. 2 (a,b) PRESS spectra from a CP head coil (a) and a 32-channel coil (b) in homogeneous fields. (c,d) 1D iDQC accumulated projection spectra obtained using the CP head coil (c) and the 32-channel coil (d) in the same/similar inhomogeneous magnetic field as in Fig. 1.
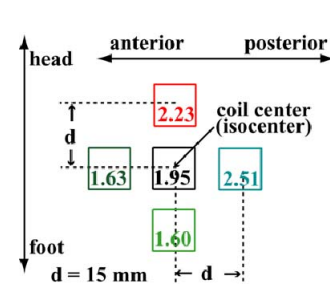

Fig. 3. Ratio of iDQC SNR of the 32-channel over CP head coils, with voxel centers at different positions as indicated. The rectangles represent voxel centers (the middle one coincides with the coil center.). The relative distance between coil and voxel centers are indicated by d.